Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at http://about.jstor.org/participate-jstor/individuals/early-journal-content.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

ON RHYTHM.

By Professor D. FRASER HARRIS, M.D., D.Sc., F.R.S.C.

DALHOUSIE UNIVERSITY, HALIFAX, N. S.

A PHENOMENON which may be called rhythmic is one that recurs at equal intervals of time or at any rate not at cognizably unequal ones. The dripping of water from a leaky tap is rhythmic, but the murmur of the brook is not. The universe is full of rhythms. The succession of the seasons, the alternation of day and night, the phases of the moon, the ebb and flow of the tide, the recurrence of spring and neap tides, the November flight of meteors, the yearly rise of the Nile, and so forth, are all examples of cosmic rhythms. The magnitude of the time interval or period of the rhythm is not of the essence of rhythmicality. Thus, the behavior of the ether in transmitting light waves is rhythmic, the frequency being only some billionths of a second; whereas the return of a comet such as Halley's to our solar system, although a matter of seventy years or so, is just as rhythmical; its reappearance is periodic.

Music is essentially rhythmic; in fact, it is the periodic character of the vibrations of the air that constitutes music as opposed to noise. The vibrations of the air objectively constituting noise are highly irregular or arhythmic.

A clap of thunder is not rhythmical. In a rhythm something recurs at equal intervals of time; if this something recurs at unequal intervals, the rhythm sometimes is spoken of as irregular. This usage would make the word "rhythm" synonymous with regular rhythm, which is the general acceptation and the one in which the term will be used in what follows. It is owing to the regularity of recurrence of eclipses, the equinox, meteors, comets, etc., that these phenomena can be predicted with an accuracy that makes astronomy as an exact science so justly admired. The periodicities of rhythms in the non-living world may be matters of years, months, weeks, days, hours, minutes, seconds or fractions of a second.

Coming now to the realm of Life, we find rhythms pervading everything. The plants, with striking regularity, have their own times each year for putting forth the buds, unfolding the leaves, bursting into flower and finally allowing all the perfumed beauty of the flower to fade in order that the fruit shall be formed as a life in death. Thus the poetess sang,

> "Leaves have their times to fall,
> And flowers to wither at the north wind's breath;
> Thou hast all seasons for thine own, O Death!"

In plain prose, there is no rhythm about Death.

"Chestnut Sunday" is approximately the same Sunday, and "Apple Blossom" week is practically the same week each year. The opening and closing of flowers is rhythmic, the rhythm depending on the waxing and waning of the intensity of daylight.

Doubtless the most familiar rhythms are in the world of animal life. Here we have rhythmic actions of animals as in flocks and herds, of animals as individuals, and of the organs, tissues and cells of the animal body. The migration of birds is annual in rhythm. It is only part of the truth to tell us that the waning light and diminished heat and food are what constrain the birds to leave us: they know *when* to leave us. Migratory birds which have spent all their lives well-fed in the captivity of Regent's Park, nevertheless become restless at the approach of autumn. Again, those animals which hibernate during the winter know when to betake themselves to their hiding-places, whence they come not forth until the spring.

The rhythm of the sexual activities of birds is one of the most characteristic things about their behavior. It is only in the spring that the "lovelier iris gleams upon the burnished dove," but it is *every* spring. Even a brainless (decerebrated) pigeon will "coo" energetically at the breeding season, although if the hen bird be placed near him he will take no notice of her. The sexual rhythm is inherent in the lower parts of the nervous system, but in the absence of the brain it is a meaningless and mechanical rhythm.

Practically all the activities of one's daily life are rhythmic; the most obvious perhaps being the regular alternation of waking and sleeping. There is a well-marked rhythm in our digestive organs, in the organs of excretion, and most pronouncedly in the beating heart.

Rhythm pervades the world of animal life: just watch that transparent jellyfish in the limpid summer sea, and you will notice how the edges of the umbrella contract or pulsate with slow and regular rhythm (about 30 in the minute). Equally obvious rhythms are those of the wings of birds and other flying things; of the legs in walking and dancing; of fins in swimming. Large birds fly with slow, leisurely rhythm, small birds with a fast one; just as tall men have a slow stride, short men a more rapid step. Regular rhythms are everywhere; if Nature abhors a vacuum, she also abhors fits and starts: living Nature does everything "decently and in order."

The periodicity of the heart's action is an excellent example of a rhythm of animal origin. Seventy-two times in the minute this wonderful hollow muscle contracts (systole) on the contained blood forcing it out into all the arteries of the body, and seventy-two times in the minute does it dilate (diastole) and suck blood in from the veins leading to it. The duration of its cycle is therefore eight-tenths of a second (60/72), and in health during the many years of a long life it practically does not vary from this value. If, for more than a few minutes, the heart's rhythm remains distinctly irregular, then we conclude that something is amiss with this wonderful organ within our breast.

Sometimes we come across a heart with a congenitally fast rhythm, a condition called tachycardia, and sometimes one with an abnormally slow rhythm, a condition called bradycardia. Whereas the rhythm of the heart-beat is for each individual a certain average rate, it varies in different individuals according to height and age. Thus, tall persons have slower hearts than short people; and infants have a heart rate about twice as fast as adults. The whale and the elephant have very much slower heart-beats than the mouse or the sparrow. The heart-beat in these small animals is so fast that the pulse can not be counted in the usual way: until recently we had no reliable information about it, but by an electrical method used by a physiologist, Miss Buchanan, D.Sc., working in Oxford, it has been ascertained with great accuracy.

The pulse-rate, which is the same thing as the heart-rate, is very much slower in the cold-blooded than in the warm-blooded animals. Thus, in a fish or frog the heart contracts only about forty times in the minute, or about half the mammalian rate. This relatively slow rate can be quickened by making the heart beat in warm salt water, when the rate can be made to exceed that of the normal mammalian heart. A further study of the warm-blooded heart proves to be full of interest. It can be accelerated by warmth and slowed by cold; but it is its affectability by nerve impulses which is so remarkable. It is a matter of common knowledge that the heart can be made to beat much faster at one time and slower at another through nerve impulses alone. Everybody knows that emotions can influence the heart very markedly. Thus, of course, it has come about that "the heart" and certain emotions are taken as synonymous. Certain emotions "disturb it" in that some cause it to beat more rapidly, and some slow it and enfeeble it.

Now physiologists have discovered two distinct sets of nerves which influence the heart-rate; the one set on being stimulated makes the heart faster and stronger (accelerator and augmentor nerves), the other set on being stimulated makes the heart beat more slowly or may stop it altogether (inhibitory nerves). Evidently the former set arouses the heart to greater activity, the latter set induces in it less activity than normal.

The rhythmicality of the heart is not conferred on it by the action of nerves or by the presence of blood or the temperature of the blood, or by any other "external" condition: its rhythmicality is inherent in it, is spontaneous (autogenic). The rhythm of the heart is of the essence of its life: the microscopic cells of the embryo heart beat with a rhythm as soon as they are perceptible at all, and long before nerves have reached them or any blood has been formed.

Spontaneous rhythmicality is the great mystery of life, the central puzzle in biology: if we knew what rhythm really was, understood it "all in all," we should "know what God and man is." The heart is not the only rhythmic portion of the circulatory system. In all animals, portions of the large veins have the power of rhythmic contraction—in the bat sixteen times per minute—and in some animals (frogs, for instance) there are pulsatile sacs or lymph-hearts, dilatations of the lymphatic vessels beating visibly under the skin of the back.

Many other organs exhibit rhythms. The activity of the stomach is rhythmic, also that of the intestines; over which waves of contraction pass at short intervals, the activities also of the gall-bladder, the urinary bladder, and the uterus are all rhythmic.

An interesting thing about rhythmic organs is their inability to have the rate of their rhythm forced beyond a certain limit. No amount of stimulation of the accelerator nerves can increase the rate of the heart-beat beyond a certain limit. Similarly, heating the heart will raise the rate of the rhythm, but only up to a particular figure which can not be exceeded. Working with the pigeon, the author found that the greatest number of beats per minute which the heart (auricle) could give was 300, or five a second; and beyond that it was not possible to force it. Not only, then, is rhythmicality inherent in the living substance of the heart (cardiomyoplasm), but also a power of resisting all influences to accelerate it beyond a certain limit, a kind of "functional inertia," as the author has called it.

Let us now take another example of rhythmic activity as seen in the cilium. A cilium is a minute, whip-like process of living protoplasm projecting from the surface of the cell. There are millions of these cilia covering the mucous membrane of nose, throat and bronchial tubes, where they are for the purpose of lashing mucus, dust and germs towards the nostrils and mouth, respectively. Now, these cilia lash backwards and forwards at a characteristic rate of ten to twelve times in the second. Just as the heart makes 72 systoles and 72 diastoles in a minute, so the cilium bends forwards ten times and backwards ten times in a second, or six hundred times a minute, about eight times as fast as the heart. Otherwise put, the period of ciliary oscillation is one tenth of a second instead of eight tenths.

But the rhythmicality of the cilium is as inherent as that of the heart. The cilia receive no nerves, therefore not being innervated they can not possess any rhythm conferred on them from outside by nerves (neurogenic). The cilia are, however, easily influenced in their rate of vibration by changes of temperature and by drugs and poisons. By warming the cilia they lash faster and faster until they attain a speed of about twenty a second, beyond which they can not go; one more example of a limit set. Conversely, cold and narcotics like chloroform slow and finally stop the action just as they do in the case of the heart.

Let us now enquire into the rhythms exhibited by muscles and nerves; almost everybody knows that muscles act (contract or shorten) by having nerve-impulses sent into them either by the will or in an involuntary manner. Soldiers who were wounded in the late war soon came to be aware that if one of their great nerves was cut, they had no longer any power to move certain muscles which they learned to call "paralyzed." Now, these nerves all come from the central nervous system, so that the impulses they transmit must also have their origin in that system. The nerve cells which give rise to these nerves and nerve-impulses are called nerve-centers, and it is these centers which emit impulses to the muscles in a definite rhythm.

Let us take the case of breathing. Normally, an adult breathes about sixteen to eighteen times a minute, that is to say, in a wholly unconscious fashion his diaphragm—the great, curved muscle between the chest and the abdomen—descends eighteen times and rises eighteen times in the minute. There is, therefore, a respiratory rhythm just as there is a cardiac and a ciliary. Now, the diaphragm would not make any descents were it not that it was receiving nerve-impulses through its nerves (phrenics). After these nerves have been cut, the diaphragm is absolutely still. Clearly, then, the rhythm of the activity of the diaphragm is not inherent, but, on the contrary, is conferred by nerves or is neurogenic. The rhythm of 18 to 20 a second must be the rhythm of discharge of nerve impulses from the nerve cells or centers from which the phrenic nerves come. It is the nerve cells that have this rhythm, not the nerves as conductors and not the diaphragm as a muscle.

The actual cells from which the phrenic nerves proceed are, however, not the breathing center, which, situated further up in the central nervous system, constrains the phrenic centers to issue their periodic discharges of nerve-impulses. It is the chief respiratory center, therefore, that has the real respiratory rhythm, which, like the heart's, varies with age and other circumstances. We know very well that the rate of breathing can be profoundly altered by emotional states; some conditions, states of excitement, greatly increase the rate, others slow it or stop it for a time, as in the phrase, "it fairly took my breath away."

Experiments have shown that heated blood accelerates the breathing and cold slows it, and there are drugs which have analogous actions. Further, the will can, for a time, abolish the rhythm altogether. Divers are able intentionally to "hold their breath"; on the other hand the will, if we so wish it, can hurry up the rhythm beyond the rate of the normal. This faculty of having a rhythm which can be altered by the will is quite a rare one amongst the centers of the nervous system.

The normal respiratory rhythm is, then, an additional example of a rhythm inherent in something—in this case in the cells of a nerve center—but capable of responding to outside influences. And again, there are limits set, for neither by the will, nor by emotion, nor by heated blood, nor by drugs, can the rate of the breathing center be forced beyond a certain maximum value.

Breathing is to all intents and purposes an involuntary, unconscious activity: the diaphragm rises and falls throughout life whether we wake or whether we sleep with a regularity that is as constant and with efforts that are as untiring as those of the heart itself. In a word, the rhythm of breathing is not voluntary, although we can interfere with it voluntarily.

But, of course, the nervous system can give us plenty of examples of rhythms of voluntary origin. Take the very simple case of tapping one's finger on the table or on an electric key. I can tap my forefinger once a second, twice a second, three times a second, and so on, until I am tapping it so fast I can barely count it. When this rate is reached, an instrument of simple construction can prove that the finger is being flexed and extended at about ten to twelve times a second. We may note in passing that this is exactly the same as the ciliary rate. Now the instrument will show that beyond ten to twelve a second the ordinary person can not go, although it is possible to train musical technicians to "trill" at a considerably greater rate than that of ordinary people. Still even for experts a limit is soon reached. The rhythm of the cells of the centers giving rise to the nerves to the fingers is evidently of this sort that whereas the cells can be made by the will to assume any slow rhythm from one to twelve a second, they can not be forced beyond that limit.

What, then, is the rate of inherent rhythm of these centers? Probably ten to twelve a second; although all physiologists are not agreed on this figure, and the point is one not suitable for discussion in the present essay. It is reasonable to suppose that these cells have a normal, natural, inherent rate of discharge which may be one and the same as their maximal rate. Neither by the will nor by artificial stimulation can this maximum be exceeded, not even when the rhythm of the artificial stimulation is much higher than twelve a second. The nerve cells have physiological inertia towards rates of stimulation greater than that of their own maximal rhythm. The respiratory center, on the contrary, we saw, had a normal rate which was *not* also its maximal.

Rhythm or intermittency pervades the nervous system. It has been ascertained that we can not utter syllables (articulate) at a greater rate than ten to twelve a second. What we may call the articulation center has its upper limit set at that figure which we have so frequently met with. The numerical identity of the rhythms of cilium, musculomotor nerve-center, and articulation center can not be accidental.

The periodicities of insects' muscles are of the following orders: The wings of the dragon-fly vibrate at 28 a second, those of the wasp at 110, of the bee at 190, and of the house-fly at 330 per second. The late Professor Mosso asserted that the pitch of the note of a bee setting out on its day's rounds was perceptibly higher than that of the note heard at the close of the day.

It is probable that the receiving or sensory portions of the brain are constructed in such a manner that they, too, have limits in dealing with rhythmic or intermittent presentations.

The spokes of a slowly rotating bicycle wheel can be perceived as separate bright lines, but when the wheel is revolving rapidly the individual spokes fuse into one bright metallic surface, just as the separate slats of a paling viewed from an express train fuse into one continuous surface. The grooves of the milling on the edge of a metal disk spun rapidly under the finger are perceived as constituting a rough but continuous surface. The fusion of the members of a series of instantaneous photographs of moving objects presented in very rapid succession to the eye, as in the kinematograph, is due to this incapacity of the brain to resolve as distinct in consciousness the separate components of the physical series. If the interval between the successive impressions is longer than about 1/40th–1/50th of a second we do not get fusion, but the well-known and disagreeable state of "flicker." These and many other cases prove that there are strict limits to the perception of rhythms by our brains.

The causes of vital rhythms and periodicities are virtually unknown. Physiologists can describe vital rhythmic actions in their own precise language, but that is all. To say that the cardiac cycle is constituted by the two alternating and opposite phases of katabolic systole and anabolic diastole does not bring us any nearer an understanding of the cardiac rhythm. Protoplasm in general tends to act intermittently. Just as a single tap given to a jelly or to a spring will make these oscillate or vibrate for some considerable time thereafter, so a single or continued stimulus given to living matter will cause it to discharge energy in a vibratory or oscillatory manner.

Nor do we comprehend any better the significance of the particular time-duration of the interval between the recurring events which are being studied. Why, for instance, should the heart beat 72 times a minute and not 7 or 700? Why should we breathe 18 times and not 8 or 80 times a minute? Why should the cilium bend 10 times a second as its normal rate and just twice as fast, but no more than that, when urged to do its utmost? These things are mysteries. The rhythms of functional activity in the female reproductive organs are familiar facts of physiology, but what induces the rhythm and why the periodicity should be as it is are problems at present entirely unsolved.

Probably the necessity of rest to prevent fatigue or exhaustion is one of the purposes of vital rhythms. The heart, for instance, can continue to beat so indefatigably just because the duration of its time of rest (diastole) in the cycle is longer than that of its activity (systole). We sleep by night in order to be active by day. All work and no rest is a physiological outrage: rhythm is an expression of that physiological normality in which work alternating with rest is most economically performed.

It is the most familiar things in life that stand most in need of explanation. Rhythmic action is very familiar, but great is the mystery of rhythmicality. That the heart should exhibit its livingness by phasic activity, that the periodicity of these phases should be controlled by nerves and influenced by certain environmental conditions, are the very A, B, C of physiology, but they are also the alpha and the omega of physiological problems.